Fifth Quarterly Progress Report

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Feasibility of an Intra-Neural Auditory Prosthesis Stimulating Electrode Array

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1. Introduction

The objective of this research is to evaluate the feasibility of intra-neural stimulation as a means of auditory prosthesis. We are stimulating the auditory nerve with penetrating multi-channel electrode arrays and monitoring the tonotopic spread of activation in the central nucleus of the inferior colliculus (ICC) of cats.

2. Summary of activities for the quarter

In the present quarter, we conducted acute physiological experiments in six cats. Five of those experiments yielded useful data regarding ICC responses to acoustic, intra-scalar, and intra-neural stimulation and, in two animals, auditory nerve responses to acoustic stimulation. Work in previous quarters has focused on a lateral, trans-bulla approach to the modiolar portion of the auditory nerve. The experiments conducted this quarter began our characterization of intra-neural stimulation using a sub-occipital approach to the intra-cranial portion. The principal accomplishments of those experiments were the following:

- *Intra-cranial approach to the auditory nerve.* The calvarium was opened posterior to the tentorium at its lateral margin, and a portion of the lateral cerebellum was aspirated to permit visualization of the auditory nerve. In some cases, the roof of the internal acoustic meatus was opened to permit access to more lateral aspects of the nerve. ICC responses to stimulation of the intra-cranial portion of the nerve *resembled* responses to stimulation of the modiolar portion (as described in previous Quarterly Progress Reports) in that:
  - thresholds were substantially lower than for stimulation with a conventional intra-scalar electrode array (best thresholds in each of 5 animals averaged ~26 dB re 1 μA for single 40 μs/phase biphasic pulses);
  - intra-neural stimulation afforded access to fibers serving the entire length of the cochlear spiral, corresponding to characteristic frequencies (CFs) from <500 Hz to >32 kHz; and
  - time constants for 2-pulse temporal summation were in the range of 100 to 150 μs.

  The intra-cranial approach *differed* from the modiolar approach in that:
  - ICC spatial tuning curves resulting from stimulation of the intra-cranial portion of the nerve tended to be broader;
  - the map from electrode depth to ICC tonotopic place was less consistent among animals and across intra-neural penetrations, ranging from essentially no tonotopy (i.e., all stimulus sites along a 1500 μm track yielding similar ICC activation) to a monotonic progression from the basal to the middle-apical cochlear regions; and
  - access to mid-frequency CFs was more common and access to extreme high-frequency CFs less common than afforded by modiolar stimulation.
- *Further development of a guide-tube system for chronic recording from the inferior colliculus.* We modified our guide-tube system (first described in QPR4) to further restrict flexing (and breaking) of silicon-substrate recording probes. We evaluated stereotaxic placement of the guide tube and dummy probes in several of the animals, *post-mortem*. Placement was accurate and the probes penetrated the tissue layers without breakage. Further progress on chronic ICC recording now awaits delivery of custom chronic probes.

- *Recordings of auditory-nerve responses to sounds.* In 2 of the animals, we attempted to preserve hearing while exposing the nerve. Using the intra-neural electrodes both for stimulation and for recording, we alternately (1) recorded auditory nerve responses to tonal stimuli and (2) stimulated the auditory nerve electrically while monitoring frequency-specific activation of the ICC. Responses recorded from the auditory nerve using silicon-substrate electrodes ranged from robust multi-unit spike activity to (in 2 instances) well isolated single units. Single- and multi-unit recordings yielded the familiar V-shaped frequency response areas and primary-like post-stimulus-time histograms. Surprisingly, there was not a strict correspondence between CFs recorded in the nerve and tonotopic locus of excitation in the ICC resulting from electrical stimulation of the same site. That intriguing result will receive further study.

3. Plans for next quarter:

- Extend study of functional topography of the auditory nerve using the intra-cranial approach.
- Extend study of auditory nerve responses recorded through the intra-neural stimulating electrode, focusing on correspondence of acoustic frequency selectivity and ICC site of activation resulting from intra-neural electrical stimulation.
- If custom chronic probes become available, test ICC recording through the new guide-tube system.